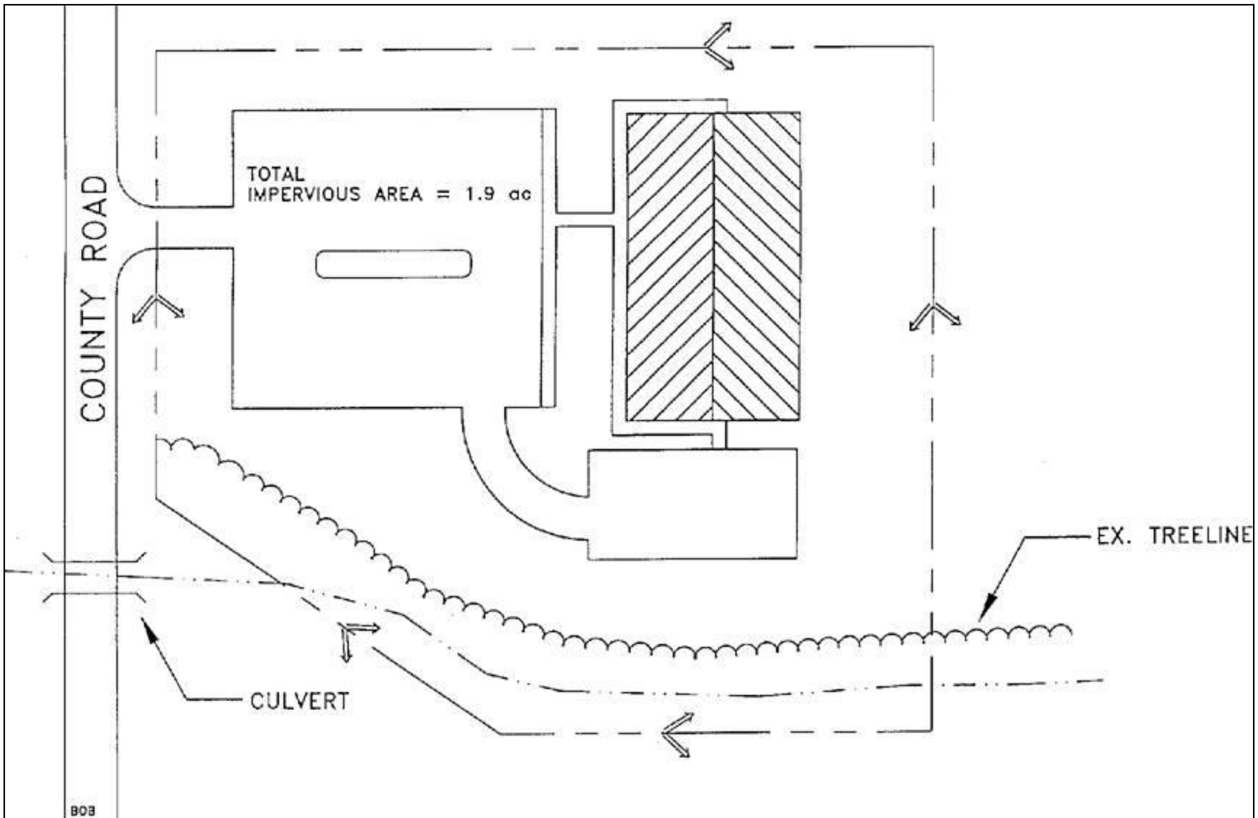
Appendix D-2

Bioretention Area Design Example



Base Data	Hydrologic Data		
Site Area = Total Drainage Area (A) = 3.0 ac Impervious Area = 1.9 ac; or I = 1.9/3.0 = 63.3% Soils Types: "C"		Pre	Post
	CN	70	88
	t_c	.39	.20

Figure 1. Etowah Recreation Center Site Plan

This example focuses on the design of a bioretention facility to meet the water quality treatment requirements of the site. Channel protection and overbank flood control are not addressed in this example other than quantification of preliminary storage volume and peak discharge requirements. It is assumed that the designer can refer to the previous pond example in order to extrapolate the necessary information to determine and design the required storage and outlet structures to meet these criteria. In general, the primary function of bioretention is to provide water quality treatment and not large storm attenuation. As such, flows in excess of the water quality volume are typically routed to bypass the facility or pass through the facility. Where quantity control is required, the bypassed flows can be routed to conventional detention basins (or some other facility such as underground storage vaults). Under some conditions, channel protection storage can be provided by bioretention facilities.

Computation of Preliminary Stormwater Storage Volumes and Peak Discharges

The layout of the Etowah Recreation Center is shown in Figure 1.

Step 1 -- Compute runoff control volumes from the Unified Stormwater Sizing Criteria

Compute Water Quality Volume, WQ_v

- Compute Runoff Coefficient, R_v

  $$R_v = 0.05 + (63.3)(0.009) = 0.62$$

- Compute WQ_v

  $$WQ_v = (1.2")(R_v)(A)/12$$

  $$= (1.2")(0.62)(3.0\ ac)(43{,}560\ ft^2/ac)(1\ ft/12\ in)$$

  $$= 8{,}102\ ft^3$$

Compute Stream Channel Protection Volume (Cp_v):

For stream channel protection, provide 24 hours of extended detention for the 1-year event.

In order to determine a preliminary estimate of storage volume for channel protection and overbank flood control, it will be necessary to perform hydrologic calculations using approved methodologies. This example uses the NRCS TR-55 methodology presented in Section 2.1 to determine pre- and post-development peak discharges for the 1-yr, 25-yr, and 100-yr 24-hour return frequency storms.

- Per attached TR-55 calculations (Figures 2 and 3)

Condition	CN	$Q_{1\text{-year}}$	$Q_{1\text{-year}}$	$Q_{25\text{-year}}$	$Q_{100\text{-year}}$
		Inches	*cfs*	*cfs*	*cfs*
Pre-developed	70	0.9	2.3	9.0	12.0
Post-developed	88	2.1	8.1	19.0	25.0

- Utilize modified TR-55 approach to compute channel protection storage volume

  Initial abstraction (Ia) for CN of 88 is 0.27: $[Ia = (200/CN - 2)]$

  $$Ia/P = (0.27)/3.4\ inches = 0.08$$

  T_c = 0.20 hours

  q_u = 850 csm/in

  Knowing q_u and T (extended detention time), find q_o/q_i for a Type II rainfall distribution.

  Peak outflow discharge/peak inflow discharge (q_o/q_i) = 0.022

  For a Type II rainfall distribution,

  $$Vs/Vr = 0.683 - 1.43(q_o/q_i) + 1.64(q_0/q_i)^2 - 0.804(q_0/q_i)^3$$

  Where Vs equals channel protection storage (Cp_v) and Vr equals the volume of runoff in inches.

  Vs/Vr = 0.65

  Therefore, $Vs = Cp_v = 0.65(2.1")(1/12)(3\ ac) = 0.34\ ac-ft = 14{,}810\ ft^3$

Determine Overbank Flood Protection Volume (Q_{p25}):

For a Q_{in} of 19 cfs, and an allowable Q_{out} of 9 cfs, the Vs necessary for 25-year control is 0.38 ac- ft or 16,553 ft^3, under a developed CN of 88. Note that 6.5 inches of rain fall during this event, with 5.1 inches of runoff.

Analyze for Safe Passage of 100 Year Design Storm (Q_f):

At final design, prove that discharge conveyance channel is adequate to convey the 100-year event and discharge to receiving waters, or handle it with a peak flow control structure, typically the same one used for the overbank flood protection control.

Table 1 Summary of General Design Information for Etowah Recreation Center

Symbol	Control Volume	Volume Required (cubic feet)	Notes
WQ_v	Water Quality	8,102	
Cp_v	Channel Protection	14,810	
Q_{p25}	Overbank Flood Protection	16,553	
Q_f	Extreme Flood Protection	NA	Provide safe passage for the 100-year event in final design

Step 2-- Determine if the development site and conditions are appropriate for the use of a bioretention area.

Site Specific Data:

Existing ground elevation at the facility location is 922.0 feet, mean sea level. Soil boring observations reveal that the seasonally high water table is at 913.0 feet and underlying soil is silt loam (ML). Adjacent creek invert is at 912.0 feet.

Step 3 -- Confirm local design criteria and applicability

There are no additional local criteria that must be met for this design.

Step 4 -- Compute WQ_v peak discharge (Q_{wq})

Step 5 -- Size flow diversion structure, if needed

Bioretention areas can be either on or off-line. On-line facilities are generally sized to receive, but not necessarily treat, the 25-year event. Off-line facilities are designed to receive a more or less exact flow rate through a weir, channel, manhole, "flow splitter", etc. This facility is situated to receive direct runoff from grass areas and parking lot curb openings and piping for the 25-year event (19.0 cfs), and *no special flow diversion structure is incorporated.*

Step 6 -- Determine size of bioretention ponding / filter area

From Darcy's Law: $\mathbf{Af = (WQ_v)(d_f)/[(k)(h_f + d_f)(t_f)]}$

Where:
- A_f = surface area of filter bed (ft^2)
- d_f = filter bed depth (ft)
- k = coefficient of permeability of filter media (ft/day)
- h_f = average height of water above filter bed (ft)
- t_f = design filter bed drain time (days) (48 hours is recommended)

$\mathbf{A_f = (8{,}102\ ft^3)(5')/[(0.5'/day)(0.25'+5')(2\ days)]}$ (With k = 0.5'/day, hf = 0.25', tf = 2 days)

$\mathbf{A_f = \underline{7{,}716\ sq\ ft}}$

Step 7 -- Set design elevations and dimensions of facility

Assume a roughly 2 to 1 rectangular shape. Given a filter area requirement of 7,716 sq ft, say facility is roughly 65' by 120'. See Figure 4. Set top of facility at 921.0 feet, with the berm at 922.0 feet. The facility is 5' deep, which will allow 3' of freeboard over the seasonally high water table. See Figure 5 for a typical section of the facility.

PEAK DISCHARGE SUMMARY				
JOB:	Etowah Recreation Center			EWB
DRAINAGE AREA NAME:	Pre-Developed Conditions			3-Jan-00
COVER DESCRIPTION	**SOIL NAME**	**GROUP A, B, C or D?**	**CN FROM TABLE 2.1.5-1**	**AREA (in acres)**
woods (good condition)		C	70	3.00
		Area Subtotals:		**3.00**
Time of Concentration	**Surface Cover**	**Manning 'n'**	**Flow Length**	**Slope**
2-yr 24-hr Rainfall = 4.1 in	**Cross Section**	**Wetted Per**	**Avg Velocity**	**Tt (Hrs)**
Sheet Flow	**dense grass**	**'n' = 0.24**	**150 Ft.**	**1.50%**
				0.33 Hrs
Shallow Flow	**unpaved**		**500 Ft.**	**2.00%**
			2.28 F. P. S.	0.06 Hrs
Channel Flow				
Total Area in Acres =	**3.00**	**Total Sheet**	**Total**	**Total Channel**
Weighted CN =	**70**	**Flow =**	**Flow =**	**Flow =**
Time of Concentration =	**0.39 Hrs**	**0.33 Hrs**	**0.06 Hrs**	**0.00 Hrs**
Pond Factor =	**1**	**RAINFALL TYPE**		
STORM	**Precipitation (P) inches**	**Runoff (Q)**	**Qp, Peak Discharge**	**Total Storm Volumes**
1 Year	3.4 In.	0.9 In.	2.3 CFS	10,049 cu. ft.
2 Year	4.1 In.	1.4 In.	3.5 CFS	15,064 cu. ft.
5 Year	4.8 In.	1.9 In.	5 CFS	20,574 cu. ft.
10 Year	5.5 In.	2.4 In.	7 CFS	26,459 cu. ft.
25 Year	6.5 In.	3.2 In.	9 CFS	34,748 cu. ft.
50 Year	7.2 In.	3.8 In.	10 CFS	41,221 cu. ft.
100 Year	7.9 In.	4.4 In.	12 CFS	47,868 cu. ft.

Figure 2. Etowah Recreation Center Pre-Developed Conditions

PEAK DISCHARGE SUMMARY				
JOB:	Etowah Recreation Center			EWB
DRAINAGE AREA NAME:	Post-Development Conditions			3-Jan-00
COVER DESCRIPTION	**SOIL NAME**	**GROUP A, B, C or D?**	**CN FROM TABLE 2.1.5-1**	**AREA (in acres)**
open space (good condition)		C	74	0.50
woods (good condition)		C	70	0.60
impervious		C	98	1.90
		Area Subtotals:		**3.00**
Time of Concentration	**Surface Cover**	**Manning 'n'**	**Flow Length**	**Slope**
2-yr 24-hr Rainfall = 4.1 in	**Cross Section**	**Wetted Per**	**Avg Velocity**	**Tt (Hrs)**
Sheet Flow	**dense grass**	**'n' = 0.24**	**50 Ft.**	**1.50%**
				0.14 Hrs
Shallow Flow	**paved**		**600 Ft.**	**2.00%**
			2.87 F. P. S.	0.06 Hrs
Channel Flow		**'n'=0.024**	**50 Ft.**	**2.00%**
Hydraulic Radius = 0.75	X-S estimated	WP estimated	7.25 F. P. S.	0.00 Hrs
Total Area in Acres =	**3.00**	**Total Sheet Flow = 0.14 Hrs**	**Total Flow = 0.06 Hrs**	**Total Channel Flow = 0.00 Hrs**
Weighted CN =	**88**			
Time of Concentration =	**0.20 Hrs**			
Pond Factor =	**1**	**RAINFALL TYPE**		
STORM	**Precipitation (P) inches**	**Runoff (Q)**	**Qp, Peak Discharge**	**Total Storm Volumes**
1 Year	3.4 In.	2.1 In.	8.1 CFS	23,320 cu. ft.
2 Year	4.1 In.	2.8 In.	10.6 CFS	30,527 cu. ft.
5 Year	4.8 In.	3.5 In.	13 CFS	37,890 cu. ft.
10 Year	5.5 In.	4.2 In.	16 CFS	45,356 cu. ft.
25 Year	6.5 In.	5.1 In.	19 CFS	55,422 cu. ft.
50 Year	7.2 In.	5.8 In.	22 CFS	63,030 cu. ft.
100 Year	7.9 In.	6.5 In.	25 CFS	70,676 cu. ft.

Figure 3. Etowah Recreation Center Post-Developed Conditions

Step 8 -- Design conveyance to facility (off-line systems)

This facility is not designed as an off-line system.

Step 9 -- Design pretreatment

Pretreat with a grass channel, based on guidance provided in Table 2, below. For a 3.0 acre drainage area, 63% imperviousness, and slope less than 2.0%, provide a 90' grass channel at 1.5% slope. The value from Table 2 is 30' for a one acre drainage area.

Table 2 Pretreatment Grass Channel Guidance for 1.0 Acre Drainage Area
(Adapted from Claytor and Schueler, 1996)

Parameter	≤ 33% Impervious		Between 34% & 66% Impervious		≥ 67% Impervious		Notes
Slope	**≤ 2%**	**≥ 2%**	**≤ 2%**	**≥ 2%**	**≤ 2%**	**≥ 2%**	Max slope = 4%
Grassed channel min. length (feet)	25	40	30	45	35	50	Assumes a 2' wide bottom width

Step 10 -- Size underdrain area

Base underdrain design on 10% of the A_f or 772 sq ft. Using 6" perforated plastic pipes surrounded by a three-foot-wide gravel bed, 10' on center (o.c.). See Figures 4 and 5.

(772 sq ft)/3' per foot of underdrain = 257', say 260' <u>of perforated underdrain</u>.

Step 11 -- Design emergency overflow

To ensure against the planting media clogging, design a small ornamental stone window of 2" to 5" stone connected directly to the sand filter layer. This area is based on 5% of the A_f or 386 sq ft. Say 14' by 28'. See Figures 4 and 5.

The parking area, curb and gutter are sized to convey the 25-year event to the facility. Should filtering rates become reduced due to facility age or poor maintenance, an overflow weir is provided to pass the 25-year event. Size this weir with 6" of head, using the weir equation.

$$\mathbf{Q = CLH^{3/2}}$$

Where: C = 2.65 (smooth crested grass weir)
Q = 19.0 cfs
H = 6"

Solve for L: $\mathbf{L = Q/[(C)(H^{3/2})]}$ **or (19.0 cfs)/[(2.65)(0.5)$^{1.5}$] = 20.3'** **<u>(say 20')</u>**

Outlet protection in the form of riprap or a plunge pool/stilling basin should be provided to ensure non-erosive velocities. See Figures 4 and 5.

Step 12 – Prepare Vegetation and Landscaping Plan

Choose plants based on factors such as whether native or not, resistance to drought and inundation, cost, aesthetics, maintenance, etc. Select species locations (i.e., on center planting distances) so species will not "shade out" one another. Do not plant trees and shrubs with extensive root systems near pipe work. A potential plant list is presented in Appendix F.

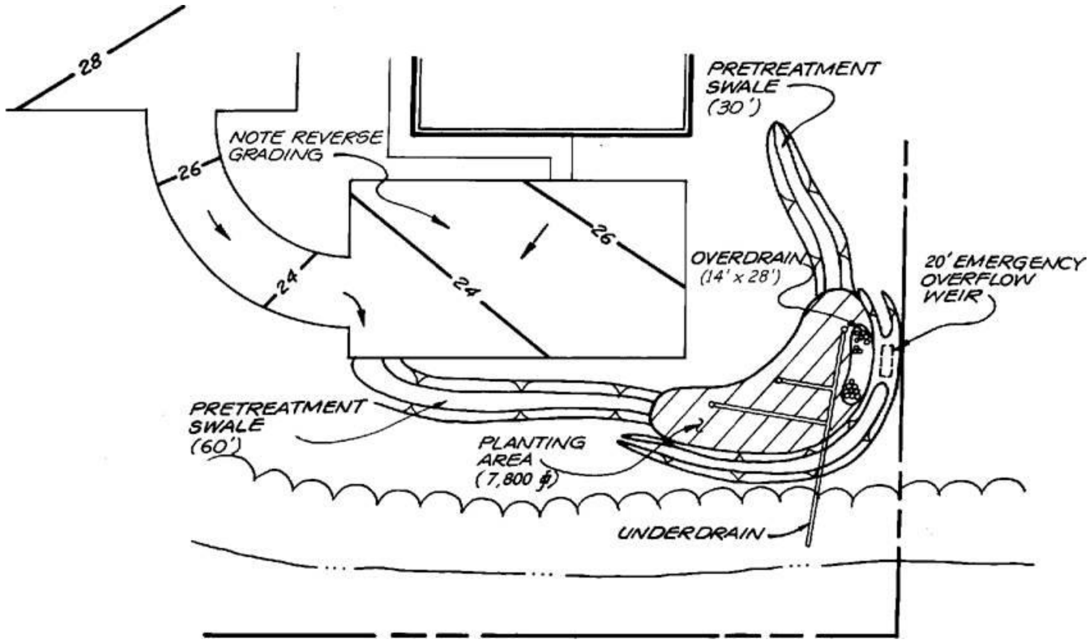


Figure 4. Plan View of Bioretention Facility

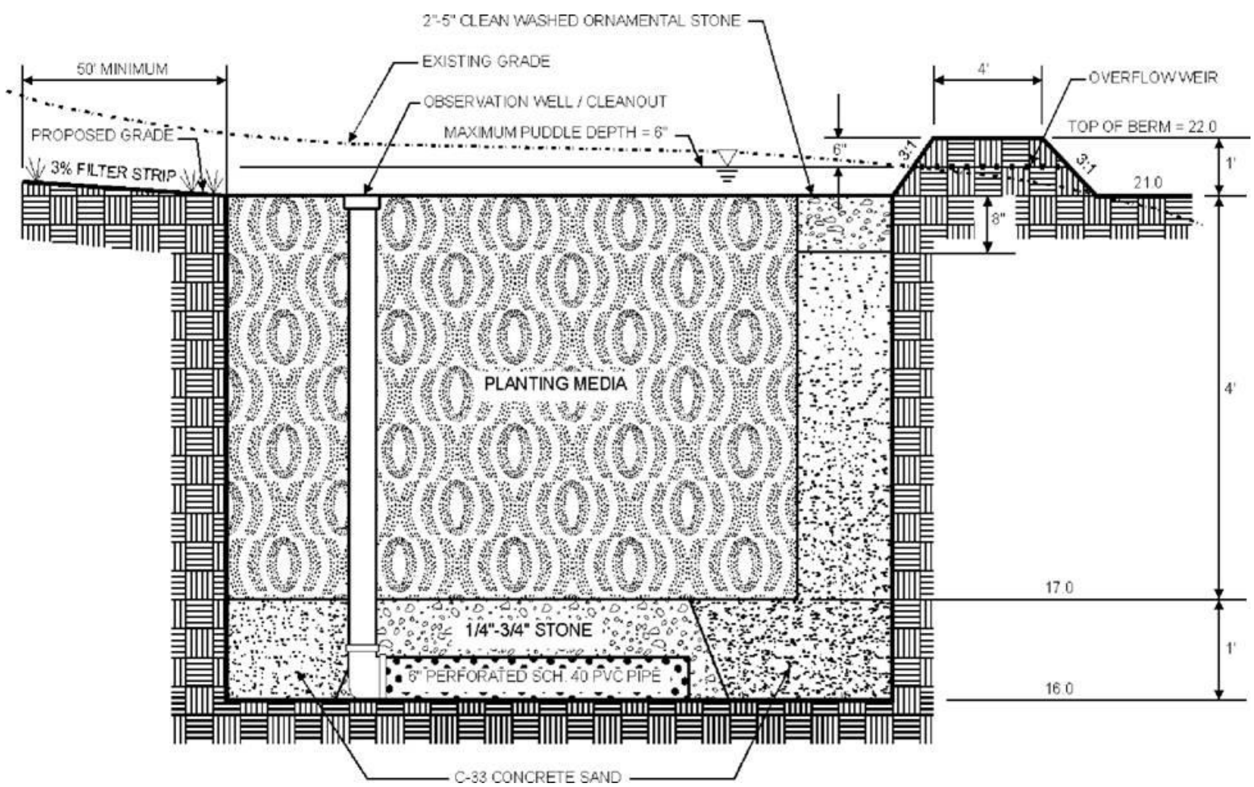


Figure 5. Typical Section of Bioretention Facility

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